THE GREEK CREW TRIALS WITH OLYMPIAS IN 1988

The second series of trials for OLYMPIAS started in the beginning of June 1988.

The ship was commanded by Lieutenant Demetrios Papadas and manned by a permanent deck crew of naval petty officers and ratings. The oarcrew were students of the petty officers academy at the ages of 18 and 19. These young men had never before been in the ship except of a short visit during the winter for educational purposes. Most of them were not familiar with rowing except of some lessons they had taken with the training "Sixteens" of their academy. Although the commanding officer and some men of the deck crew had participated in the trials of 1987 this new oarcrew mostly unfamiliar with rowing imposed the main difficutly for the planning of this second series of trials.

Until the 18th of July that the ship would be handed over to the oarcrew raised by the Trireme Trust we had one month and a half at our disposal excluding weekends and short vacation periods to train the crew, perform trials and take measurements for speed under oar, accelaration and manoeuverability under oar, effectiveness of steering oars, various trials under sail and last but not least a voyage of 140 miles around various towns of the Saronic Gulf with festivities in each town which made our schedule on arrivals and departures rather tight. So it was decided that the crew would be training in the ship until June 17th and then one week of trials and measurements out of the harbour under construction in Neon Phaliron would follow. A short vacation would be given after that to the crew until the 2nd of July that the preparations for the Saronic Gulf voyage would start.

After one week of training a remarkable progress in the oarcrew performance was evident. Although during the first three days we were rather disappointed regarding the synchronizing of oarstroke and the endurance of the crew, at the end of the week they would row for one hour continuously at an average of 30 strokes per minute giving to OLYMPIAS a maximum speed of 4 knots in good weather conditions.

On the 17th of June that the trials with measurements began, 11 men out of 200 that originally was the number of the oarcrew were out of the team because of lacking the necessary strength, and fittness to handle the heavy oars. The remaining 190 continued, most of them with blisters in their palms and chaffed bottoms but rather proud of what they had achieved up to that time, expecting with great interest the adventure of the Saronic Gulf voyage.

The Manoeuverability - Speed and Acceleration Trials

For the accurate measurements of the speed under oar, and manoeuverability, the ship's course was tracked by a shore based measuring instrument called a Geodimeter using an infra-red laser beam reflected from the ship on which was mounted an omni-derectional reflector. This instrument converted measured distances and angles into cartesian coordinates with great accuracy. The instruments and staff for the measurements were provided by the Hydrographic Service of the H.N. Except of the above mentioned instrumentation that was used for measurements, there had been installed in the ship during the winter of 1988 a digital log, a digital wind speed indicator and a wind direction indicator.

These trials took place for 5 consequent days from 17th to 21st of July in the hours between 8.00 and 15.00 in the area between the harbor of Neon Phaliron and the yaughts harbor in Paleon Phaliron. The trials began with the turning circles which is a fundamental ship trial manoeuvre that provides quantitative data on the ship's transient and steady state turning behavior. In all the tests initial speed was gained with the ship moving in a straight line and with equal numbers of rowers at work on each side; in some tests these rowers all continued working after the rudders had been applied but in others the rowers on the inside of the turn ceased work when the rudders were activated. Large protractors were used for measuring the rudder angles and to ensure that both rudders were applied equally.

Effect of rudder angle

The main yard was lowered for these tests. Angles of 22.5, 45 and 67.5 degrees were used, and the ship was propelled by the 62 oarsmen at the *thranite* level, although in the test with a 45 degrees angle they were men who normally rowed as *Zygians* or *Thalamians.* The diameters of the turning circles were 225m, 124m and 84m, i.e., they were inversely proportional to the rudder angle. The initial speeds were 4.5 knots, 3.8 knots and 3.8 knots and the loss of speed in the turns was 25%, and 20% respectively.

Effects of number and location of oarsmen during a turn

The main yard remained lowered for the first of these tests. By increasing the number of oarsmen in action from 62 to all 170 the initial speed was increased from 3.8 to 5.9 knots, and the diameter of the turn with a rudder angle of 67.5 degrees was increased from 84m to 110m. The loss of speed in turning was increased from 20% to 25% i.e. the speeds on leaving the turns were 3.0 knots and 4.4 knots respectively. After the main yard had been hoisted, the sail being brailed up to it, two tests were made to discover the effect of making the rowers on the inside of the turn (the port side) cease work when the rudders were put on, and the effect of increasing the number of rowers on the outside. In the first of these tests the 62 Thranites rowing at 29spm had attained a speed of 3.4 knots when the rudders were activated to an angle of 45 degrees and the port side Thranites stopped rowing. The diameter of the turn was 103m, whereas when all the Thranites had rowed throughout the turn it had been 124m. The comparison may not be quite fair because the yard had been hoisted and the initial speeds differed. In the second test the whole crew rowed at the outset to attain a speed of 5.3 knots before the rudders were activated and the port side rowers ceized rowing. The rudder angle was again 45 degrees and the diameter of the resulting turn was 105 m. The greater torque from having all the starboard oars rather than only the starboard *Thranite* oars in action during the turn evidently compensated for the greater resistance to turning that arose from the higher initial speed.

Several more turning circle trials were attempted at various speeds which confirmed the very good manoeuverability of the ship although also several of them could not be considered as accurate and were discarded because of the severe drifting of the ship during the turn when the wind speed was above 8 knots.

The conclusion of these turning trials is that the rudders are very effective although they increase appreciably the resistance of the ship especially when they are working at angles above 30 degrees. The rudders are correctly balanced and easy to use. Their best position for a quick turn is at 67 degrees whereupon the rate of turning of the ship at a speed of 4 knots is 2.6 degrees per second.

One turning trial was performed with the port *Zygians* and *Thranite* files of oars backing water and the respective starboard files pulling ahead. It took several training turns in order to master the syncronisation of the port and starboard oars when the first were backing water and the second were pulling ahead. During this trial turn the ship turned at a rate of 3.5 degrees per second with 23 strokes per minute rowing rate staying virtually in the same place. In order to complete the

manoeuverability measurements we had planned zig-zag trials for the last two days of this phase.

The wind speed during these days exceeded the ten knots and the drift of the ship made it impossible to take the accurate measurements needed for this particular trial.

The results of the speed under oar trials can be summarized as following. The maximum speed attained by the ship in Phaliron measured by geodimeter regarding the course and distance and by stop-watches regarding the time was 7.2 knots. This speed was kept constant for a distance of 600 meters which was covered within 2 minutes and 42 seconds. The ship's log measured a speed of 8.02 knots during the last day's trials when the ship was in Poros which is questionable because of a + or -10% log's error. During these trials both rudders were fully immersed and the yards of both brailed with the sails furled. Given that the rudders increase the resistance of the bare hull of the ship in this high speed region by about 80%, one more knot in maximum attained speed with the rudders immersed by only 1/3 is reasonable to expect.

Maximum speed with only the *Thranites* file rowing was 5.8 knots with the *Zyggians* file 5 knots and with *Thalamians* file 4 knots.

Now some brief comments concerning the crews and ship's performance in the speed trials under oar. During the first two weeks of training of these novice oarsmen and the trials under oar impending, we concluded that they could reach a good synchronization but they rowed with little body swing with a short stroke (about 40-50 centimeters instead of the 80-90 cm available) using almost entirely their arms. Effords to increase the body swing had adverse effects on synchronizaton because of lack of rowing experience.

Given that in propulsion by oars the power equals the force applied to the oar times the length of the stroke times the rate of stroke per minute (P=F*S*spm) and length of stroke could not be further increased, in order to increase P we decided to increase by practicing the force applied and the number of strokes per minute without loosing the synchronization. Of course with this technique we would loose in duration of the output since a significant part of the energy output of each oarsman per unit of time would be waisted in the efford to raise the heavy oar out of the water, make a backswing and start catching the water again.

The above were confirmed later by the speed measurements where the ship reached high values of speed but with the rather short duration of 2 min.

and 42 seconds at maximum instead of 6 or 7 minutes that an oarsmen physique makes possible. On the other hand these synchronized short and strong strokes with the oars should be the technique to achieve the highest values of acceleration in the ancient naval battles for ramming or avoiding the enemy ships in short distances.

It is also proven by statistical modelling that the synchronization of oars is better kept in the short crested and with short period waves of head seas that are met in Aegean and a *Trieres* can afford to sail, if shorter stroke is kept, because more oars are simultaneously in the water that with a longer stroke. So because of reasons of necessity so to speak OLYMPIAS was tested by the Greek Crew with the short stroke technique while later it was tested by the Trireme Trust's Crew with the long stroke technique.

As far as oars are concerned it was clear that although well balanced they were rather too heavy to handle especially for novice oarsmen. It took a lot of efford to deal with their high mass momemtum during their pulling out of the water or at the sudden change of direction from backswing to the catch during each stroke. The beams at the height of the head of *Thalamians* seemed disturbing them psychologically rather than actually, since they were afraid to hit at the end of extreme body swings.

The rudders although very efficient seemed to induce an unecessary drag at high speed because of turbulence caused by their bluff shaft cross section and their hydrodynamically poor blade shape which nevertheless is archaeologicaly justified. This makes it almost certain that in Antiquity at high speeds the rudders would be raised out of the water leaving immersed a percentage of the blade area which because of the increased speed would keep the maneuverability of the ship still at high standards.

The acceleration from stop was measured with all three rows of oars rowing and it took 32 seconds to reach a speed of 7 knots that gives an average value of acceleration of 0.1 m/sec. This value is greater if it is measured for smaller speeds from stop. The detailed results of the above mentioned trials as well as the results performed by the Trireme Trust crew in Poros will be given in detail in a report which is expected to be published until the end of this year.

I will now proceed with the trip of *Trieres* in the Saronic Gulf giving it as a summary of a diary together with the most important observations that can tell us a lot about the ship's performance and the crew's life not in so to say "laboratory conditions" but in actual and demanding voyages where the duration, the weather

conditions, the crew's level of training, the physique and stamina play their part which is not to be underestimated at all.

On Saturday June 9th at 7.50 in the morning, OLYMPIAS departured from Neon Phaliron with destination to Salamis where it was expected at 17.00 to begin the festivities of the farewell for the Saronic Gulf voyage.

There was a cross head breeze blowing with a speed of 4 knots. The rate of rowing was 32 strokes per minute and the ship's speed 3.2 knots. The speed remained constant at 3 knots for the next 4 hours. *Thalamian* oars men interchanged position with *Thranites* when OLYMPIAS had already covered 11.2 miles. There was an increased need for potable water and the two inflatable service boats brought new bottles from the landing ship of the Navy that was accompanying OLYMPIAS. At 12.00 the ship anchored at the Kanakia bay and the crew took its lunch.

At 12.30 and after a half hour lunch and rest the ship departed. The wind had turned Southward with a speed of 13 knots. The relative direction to the ship's course was 155 degrees and the main sail was unfurled giving to the ship a speed of 3.5 knots. This lasted only half an hour and afterwards the wind fell. The *thranites* file started rowing keeping the speed at 2.5 knots. The wind changed direction very often. We observed that the ship could sail when the apparent wind angle was above 75 degrees abeam. A short in duration South gentle breeze of 16 knots gave to the ship the speed of 6 knots and at 15.00 we arrived in Salamis having covered 21.5 miles.

OLYMPIAS sailed from Salamis with destination to Aegina on Monday July 11th on 7.40 in the morning for the part of the voyage which turned to be the most pleasant and easy because of the helpful wind. A breeze from north eastern direction with a speed of 12 knots was on the starboard beam of the ship. The sails were hoisted and brailed before casting off from the quay and proceeding clear under oars. After that both sails were unfurled and trimmed giving to the ship a speed of 3.5 knots.

The wind turned into gusty changing often direction within a range of 40 degrees and although the wind direction indicator was showing 90 degrees abeam the sails could not be regulated in a steady position going limp and frequently backing. These sudden gusts reaching sometimes the speed of 17 knots caused appreciable rolling of the ship. To reduce it the boat sail was furled leaving the mainsail to draw the ship at a speed of 6.5 knots. At 8.50 hours the ship tacked getting the wind which had weakened to a speed of 7 knots from the port beam and attaining a speed of 4.5 knots.

After one hour the boat sail was unfurled and *Zygians* and *Thranites* files started rowing increasing the ship's speed from 4.5 to 6.6 knots. This went on for 30 minutes.

Although the rowing efficiency was reduced because of the increased relative velocity of the water, it showed clearly that sails and oars could be used simultaneously in antiquity if the circumstances would call for that. During this leg of the voyage were present the arcaeologist Mr. Spondilis and Mr. Timothy Shaw as observers. Only the port rudder was used during this part in order to reduce induced drag and observe the performance of the vessel under this condition. The ship sailed balanced and stiff behaving in the same way as if both rudders were used but with the speed increased by 9%.

At 11.30 after 3 hours and fourty minutes OLYMPIAS arrived in Aegina covering the 16.18 miles distance from Salamis at an average speed of 4.6 knots. The conclusions of this leg of the voyage are very useful and confirmed the first impressions about sailing performance of the ship which we had from the previous year.

The leg from Aegina to Poros started the next day July the 12th at 6.40 in the morning. Alight North-eastern breeze blowing with a speed of 7 knots from the port beam of OLYMPIAS gave hopes for an easy voyage. Professor Morrison and Mr. Timothy Shaw were abroad as observers. The ship attained with both sails unfurled and trimmed a speed of 5.5 knots and with the wind abeam at 90 degrees it crossed the Moni Straights.

At 8.20 hours the wind weakend to a speed fo 2.2 knots being on the port quarter of the ship which sailed at a speed of 2 knots, indicating that the sailing efficiency of the sail rig was about 90% at this moment. A problem to the hauling halyard of the main yard on the masthead appeared at this time and one man of the deck crew was hauled using the halyard up to the top of the main mast to repair it. This repair work lasted 15 minutes.

The ship turned slightly its course having now the wind abeam at 70 degrees. The sail rig after the necessary trimming performed without any backing in this close angle to the wind defining its limits and capabilities. The ship's speed was 2.7 knots and the wind's velocity 4.7 knots. This course of the ship continued for three more hours with frequent changes fo the wind direction which oblidged the deck crew to deal very often with the trimming of the sails keeping an average speed of 3 knots.

As soon as the ship entered the Poros Straights both sails were furled and OLYMPIAS was rowed by *Thranites* and *Zyggians* at a speed of 4.3 knots with 32 strokes per minute. In a small bay close to the Poros harbour the ship anchored and a trial of quick abandoning of the ship with all crew jumping with order to the sea took place. The oarcrew jumped from the outriggers in an orderly way, by file *Thranites* first, then *Zyggians* and lastly the *Thalamians*. In this first trial it took 70 seconds for the oar crew to abandon the ship.

The ship remained at anchor for 6 hours and the crew rested and swimmed. After this trial the ship sailed again at 18.30 for it's mooring in the quay of Naval School in Poros where it arrived at 19.20 hours.

The next day July the 13th at 6.30 the ship sailed with destination to Hydra. In the ship were present Prof. Morrison and Dr. Vichos as observers. At 7.10 hours both sails were unfurled in order to catch the morning breeze of speed 3.3 knots blowing from the starboard quarter which gave to the ship a speed of 2.9 knots. At 8.10 the ship approached the Tselevinia Straight with a speed of 4.0 knots. Some observations about the resistance of the rudders took place at this point with the port rudder pulled out of the water and then immersed again. At a speed of 4.0 knots each rudder contributed to a 10% decrease of the speed of the ship. At 9.15 the ship was 3.1 miles away from the harbour of Hydra. At this point the wind had gradually diminished to a speed of 1.0 knot so the sailes were furled and the ship was rowed by all files of oars at a speed of 4.0 knots. A short sprint was attempted where the ship reached a speed of 7.8 knots as measured by ship's log. At 10.20 the ship arrived in Hydra having covered 13 miles in 3 hours and 50 minutes.

On Thursday 14th of July at 6.45 OLYMPIAS sailed for Poros. Getting a Nothern breeze of 3.3 knots ahead the ship was rowed by *Thranites* only reaching a speed of 3.3 knots. The pulling out of the rudder oars by 2/3 gave a small increase to the speed making it 3.7 knots indicating again that their drag in these low speeds is about 10% while it is greatly increased at higher speeds because of the wave making resistance of the rudder shaft. A short sprint with the *Thranites* oars gave to the ship a speed of 5.5 knots. After one hour of rowing the *Zygians* took their turn to the *Thranites* oars. At 8.20 the breeze coming from ahead picked up to a velocity of 12 knots and the ship's speed dropped to 2.2 knots with only the *Thranites* rowing. After one hour the *Thalamians* who were resting up to that moment took their turn to the *Thranites* oars and the ship reached a speed of 3.2 knots with 32 strokes per minute. The ship arrived in Poros at 11.30 covering the distance of 13.3 miles in 4 hours and 45 minutes at an average speed of 2.8 knots by oars in a head wind of 12 knots.

The next morning at 6.30 the ship sailed with destination to Epidaurus. The relative velocity of the morning Northern breeze was 7 knots having a direction 10 degrees to the port of the ship's bow. Only the *Thranites* were pulling and the ship's speed was 3.2 knots. After two hours of rowing the morning breeze picked-up to a gentle breeze of velocity 13 knots steadily increasing and the ship's speed fell to 1.9 knots. The wave height increased to 0.6 meters. The ship was rowed now by *Thranites* and *Zyggians* reaching a speed of only 2.8 knots. At 10.00 and with OLYMPIAS sailing under the same conditions with a wind speed of 15 knots 18 degrees from the starboard side of the bow a drifting fo about 10 degrees was recorded. The files of oarsmen interchanged positions every hour with one file resting at a time. At 10.30 the course was altered westwards and having now the wind at the starboard beam both sails were unfurled and trimmed and the ship attained a speed of 3.5 knots. The OLYMPIAS arrived in Epidaurus at 15.00 covering a distance of 22 miles in 8 hours and 10 minutes at an average speed of 2.7 knots.

On Sunday the 17th of July at 6.30 the ship sailed for it's last length of the Saronic Gulf voyage from Epidaurus to Poros. The poor wind conditions prevailed in the greatest part of this leg where the ship was rowed by two files of oars for 4 hours reaching the average speed of 3.5 knots. At one part of this voyage we had a wave height of 0.8 meters from the bow and useful observations about the rowing conditions in rough water were made.

It was really difficult for the oarsmen to synchronize their stroke along the length of the ship since there were sections of the ship that the oars were catching water being at the crest of the wave while at others the oars were in the air being at the trough of the wave. The speed under these circumstances was reduced to about 2 knots. The part of the distance that was covered under sail was 7 miles at an average speed of 4.0 knots.

The total distance of this length which was 22 miles was covered in 7 hours at an average speed of 3.1 knots. The ship arrived at the bay next of the Poros harbour at 13.30 and stayed there at anchor for half an hour. New trials for quick abandoning of the ship took place there and the time was shortened to 24 seconds that took the whole oarcrew to abandon the ship in order.

With this arrival in Poros ended the first part of 1988 trials and with this occasion I want to express once again the thanks of the International Committee of Experimental Archaeology for OLYMPIAS and of me personally as the Trials Master to the crew of the ship and especially to the young oarsmen who made it possible to have all these results despite the difficulties.

After the voyage in Saronic Gulf we were able to draw useful conclusions about the performance of the ship's sailing rig. The observations of log speed and apparent wind speed and direction have been plotted after resolution into true wind speed and direction relative to ship's head on polar diagrams. These diagrams show, irrespective of wind speed the ratio of ship speed to true wind speed in various wind directions what is called the sailing efficiency. As we can see in the polar diagram the speed ratio is decreased with increasing wind's speed because sail is shortened in stronger winds and the resistance of the hull in the water increases as the cubic power of ship's speed. Maximum speed recorded was 8.5 knots in winds of 15 to 18 knots 30 to 40 degrees abaft the beam.

Ship's windward ability as observed showed that she can be sailed as close as 70 degrees into the apparent wind. Speeds of more than seven knots were often reached in quartering and following winds of around 15 knots apparent speed under full sail. In ideal conditions OLYMPIAS may exceed 10 knots under sail. Tacking and wearing can be carried out easily with little loss of speed owing to the ship's owing to the ship's resposiveness to the helm.

The lightning of the mainmast and main yard made for easier handling of the main sail although there is still some extra weight in the main yard that could be trimmed down. A view is also expressed that the main sail could safely be increased in area by increasing it's breadth and the length of the main yard.

The ship answered the helm well in all conditions of sailing yet met. The best combination of rudders and their degree of immersion when under sail has so far not been fully investigated. However during the trials good steering was experienced with only the leeward rudder in the water.

The excellent sailing performance strongly indicates that *triere* is made passages routinely under sail whenever the wind served and under oar only when pressed for time and worthwhile progress was possible by that means. That passages under oar were the exception rather than the rule could explain why explicit references in ancient literature are all to passages under oar while there are not to passages under sail. Such a predominant use of sail by fighting ships on passage would not in any way reduce the need for good performance under oar, essential to tactical mobility in combat before the invent of more efficient rigs and sailing warships. Until the fifteenth century AD ships needed to be equipped with both oars and sails to enable them to be deployed over appreciable distances while oars were equally important in minimising delays.

Behaviour in Waves

The behaviour of the ship in waves was very much what would be expected in a ship whose length was more that eight times the waterline breadth. The sense of pitching was especially felt among crew members stationed near the ends of the ship. No slamming of the bow to waves was experienced, presumably because whenever the forward part of the hull did emerge from the water when pitching, its sections were steep enough to prevent impact on reentry. When pitching, particularly on a head wind, longitudinal flexing of the hull was quite evident as waves passed under the vessel. In these trials the ship proved to be safe within the conditions for which it was designed, that is, in waves of up to about one meter in height.

In anchoring, the need was felt to put weights on the anchor ropes to obtain the same effects as those normally nowadays achieved by the use of chain in place of rope, mainly a horizontal pull on the anchor and "spring" in the cable which, hanging in a deep catenary would prevent sudden tightening should the ship pitch in waves while at anchor. Pulling the author by hand, proved slow and laborious owing to the limited working space and therefore the small number of men on the ropes. This needs further consideration in future operations with the reconstruction.

The main question that I had when we held the first discussions about the construction of OLYMPIAS in Greece came naturally to me once again after six years of common living experiences so to speak with her:

— Is it possible that such a ship could be seen sailing in Aegean 2500 years ago?

The answer now came unforced.

— Yes, OLYMPIAS is a *Trieres* that could be existing in Antiquity. Yes, there are areas that this ship can be improved as far as sailing rig-oars-internal arrangenment are concerned and it is worthwhile to continue the trials and improvenents in order to exploit and improve her limits, a process that without question was followed by ancient Greeks as well.

Commander Stavros Platis H.N.